

Structure and Properties of Atoms

PS-2 The student will demonstrate an understanding of the structure and properties of atoms.

PS-2.1 Compare the subatomic particles (protons, neutrons, electrons) of an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity).

Taxonomy Level: 2.6-B Understand Conceptual Knowledge

2.7-B Understand Conceptual Knowledge

Key Concepts:

Sub-atomic particles: proton, neutron, electron

Energy level

Electron Cloud

Nucleus

Previous/Future knowledge: In 7th grade, students recognize that matter is composed of tiny “particles called atoms” (7-5.1). Students have no prior knowledge about the structure of the atom. In Physical Science, students identify and compare the *subatomic* particles that compose atoms and develop a fundamental concept of the role that these three particles have in determining the properties of the atoms that they compose. The concepts addressed in this indicator are the foundation for the Atomic Theory, the idea that the physical and chemical properties of substances are functions of the particles of which they are composed, and are, therefore, prerequisite for PS-3 (properties of matter), PS-4 (chemical reactivity) and all subsequent study of chemistry.

This is an introduction so it is essential to emphasize a concrete, descriptive approach.

It is essential for students to compare subatomic particles by

- **Particle type:**
 - o Know that the atom is composed of *subatomic particles* (*protons, neutrons, and electrons*) that affect the properties of an atom.
- **Particle mass:**
 - o Understand that protons and neutrons have about the same mass.
 - o Understand that the mass of an electron is much less than the mass of protons and neutrons (It is not necessary for students to know the exact mass of the particles).
- **Particle charge:**
 - o Understand that protons have a positive charge; know that neutrons have no charge.
 - o Understand that the net charge of the nucleus is positive and equal to the number of protons.
 - o Understand that electrons have a negative charge.
 - o Understand that there is an attractive force between negative electrons and positive protons (unlike charges attract).
 - o Understand that there is a repulsive force between electrons and electrons, and between protons and protons (like charges repel).
 - o Understand that atoms are neutrally charged when the number of electrons is the same as the number of protons.
- **Particle location:**
 - o Understand that protons and neutrons are tightly bound in a tiny *nucleus*.
 - o Understand that the nucleus is located in the center of the atom with the electrons moving in complicated patterns in the space around the nucleus.

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- o Understand that the electrons have energy and that as the level of energy (*the energy level*) of an electron increases, the electron is likely to (will probably) spend more time further from the nucleus.
- o Understand that the total region in space where electrons are likely to be found around the nucleus of an atom is often called the 'electron cloud'.
- o Understand that as the *energy levels* of electrons increase, the regions of space where the electrons are likely to be found are at increasing distances from the nucleus.
- o Electrons with more energy occupy higher energy levels and are likely to be found further from the nucleus.
 - There are a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus.

It is not essential for students to

- Know the exact number of electrons that can occupy each energy level.
- Know that the main energy level occupied by an electron is a description of the principal quantum number.
- Understand the nature of the other quantum numbers (angular momentum quantum number, magnetic quantum number, or spin quantum number).
- Understand the forces holding the nucleus together.

It is essential that students understand the role that subatomic particles have in determining the properties of atoms:

- **Identity of the Atom:**
 - o Understand that the number of protons determines the identity of an atom (an element).
 - o Understand that while atoms of the same element have the same number of protons, the number of neutrons may vary (PS-2.2).
 - o Understand that an atom of a given element may lose or gain electrons yet it still remains the same element.
- **Mass of the Atom:**
 - o Understand that the total number of protons and neutrons within its nucleus is a major determinant for the mass of the atom, because the mass of the atom's electrons is insignificant by comparison.
- **Reactivity of the Atom:**
 - o The particles in the nucleus of the atom do not change in a chemical reaction.
 - o Chemical reactions occur because the electrons around the atoms are exchanged or shared. The number of electrons in the outer energy level of the atom and the relative distance from the nucleus of these outer-energy level electrons determine how the atom will react chemically.
- **Volume of the Atom:**
 - o The volume of the 'electron cloud' determines the volume of the atom. The volume of the nucleus of a typical atom is extremely small when compared to the volume of space occupied by the atom's electrons.

It is not essential for students to

- Understand the contributions of shielding effect and nuclear attraction to atomic radius.

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Misconception: (Teacher note)

Most students have the misconception that an atom is like the diagrams in their textbooks: a nucleus roughly half the size of the atom, electrons orbiting in perfect circles. Students need to understand that this is a convenient way to represent the parts an atom, but not a dimensionally accurate representation. A drawing such as the one below also gives students the incorrect impression that electrons orbit the nucleus in regular, circular paths.



It is important that students can visualize the nucleus of an atom as a tiny speck in the center of an atom and the electron cloud as an area outside the nucleus where electrons are moving erratically like bees around a beehive. The electrons with more energy can move further from the nucleus, those with less energy stay closer. The space where the electrons are moving makes up the vast majority of the volume of the atom.

In order to visualize the perspective, if the nucleus of an atom is represented by a speck the size of the period at the end of this sentence, the first electrons are likely to be found in a region at a distance away from the speck equal to the length of a football field.

Assessment Guidelines:

The first objective of the indicator is to compare the three primary subatomic particles with regard to mass, charge and location; therefore the primary focus of assessment should be to detect correspondences between and among these particles with regard to these three properties.

In addition to compare, assessment may require students to

- Illustrate with drawings or diagrams that depict the charge, and mass of the three particles;
- Classify the three particles based on the characteristics of mass, location, and charge;
- Summarize the characteristics of the subatomic particles;
- Identify the charge of each particle, the charge of the nucleus, and the charge of the electron cloud;
- Recognize that protons and neutrons are located in the nucleus and electrons in the electron cloud;
- Recall that the nucleus is a densely packed core and the electron cloud as an area of vast space by comparison.

The 2nd objective of the indicator is to explain the role that the three primary subatomic particles have in determining the mass of the atom, the volume of the atom, the identity of the atom and how the atom is likely to react chemically, therefore, the primary focus of assessment should be to construct a cause and effect model of the role that each sub-atomic particle plays in determining the properties and characteristics of atoms.

In addition to explain, assessment may require students to

- Infer how each characteristic (identity, mass, volume, and or reactivity of an atom) would be affected if the number of particles changed;
- Summarize the significance of each subatomic particle in determining the atom's characteristics;
- Recognize the role that each particle has in the characteristics of an atom.